SECTION III:

HISTORY OF PROTECTIVE GLAZING

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HISTORY OF PROTECTIVE GLAZING IN EUROPE

The **Corpus Vitrearum Medii Aevi (CVMA)** in Europe records the earliest important protective glazing (PG) installation known, based on reliable documentation; the application of external diamond-pane leaded glazing over the "Five Sisters" window at York Minster Cathedral, England, in 1861. This medieval window dates from the third quarter of the 13th century and contains approximately 1,250 square feet of glass. More PG was installed over the west and east windows the following year. The York Minster installations are well documented and therefore an extremely important case study in the history of PG. Records show that the same energy, aesthetic and conservation concerns prevalent in America today were debated over the York Minster protective glazing a century ago!

> The Yorkshire Gazette of June 29, 1861 has an article on the heating of York Minster. Twelve stoves were expected to guarantee a temperature of 50°F at York but the great expanse of glass made this difficult to achieve. *"The Dean and Chapter have determined to glaze the outside of 'the five sisters' window, in the North Transept, with plate glass, to obviate the great draught of cold air through (sic) that expanse of glass; this work will also have the additional advantage that it will protect the beautiful stained glass which in heavy gales from the north is in danger of sustaining considerable damage."*
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> In the York Herald on July 17, 1862, a letter to the Editor complained about *"the covering of the Five Sisters and the Great West Window with plate glass which takes away the depth of slay of the mullions and richness of effect,...besides forming a space for dust to lodge in."*

Subsequent mention of this early PG installation occurred in 1906 and 1907 in papers concerning the restoration of York Minster. Large plates of 'Hartley's rough patent glass' had been used as the 1861 PG, but these plates had been fastened with iron bars, which, due to expansion and contraction, had broken the PG and split the stone mullions. These broken plates were to be replaced with a 'complete skin of clear crown glass in diamond quarries, similar to work already done at the Chapter House.[1] In 1921, the **Society for the Protection of Ancient Buildings** suggested venting the external glazing over York Minster's windows, *"especially on the south side, to leave opening in the clear borders of the internal glass at the top and bottom of each light. These openings should be filled with copper wire gauze to keep out insects...The object of this is to provide ventilation between the glasses and to minimize the effect of condensation produced by changes of temperature in an unventilated space."*[2] Seven years later, the Society changed its opinion to *"no protection be put to the glass unless it is very certain that there is real risk of damage happening for want of it."*[3] According to Mr. Peter Gibson, the former stained glass conservator at York, *"the current English view is to install protective glazing only when necessary and to vent it to either the inside or outside, just vent it."*

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[1]CVMA Newsletter 13, February 21, 1975, Peter Gibson.

[2]CVMA Newsletter 14, April 21, 1975.

[3]Ibid.

During the 1970s, Gibson researched the history of several other English protective glazing installations which are recorded in CVMA newsletters:

1. A church in Cothele, Cornwall, is known to have had PG removed in 1880. It is not known when the PG was installed, but the quarries produced a diamond-shaped corrosion pattern on the outside of the medieval window. The 1480 window was possibly "altered" between 1535 and 1540. Unfortunately, this building was demolished when the CVMA printed this information.[4]

2. The William Peckitt Commission Book at the York City Art Gallery contains an entry which refers to glazing on a William Peckitt window at Audley End in Essex. The entry, dated March 1782, records the purchase of nine panes of strong glass for fixing behind the painted glass in the frame for the panel made for Sir John Ramsden, High Sheriff at Byram Hall, near Ferrybridge, Yorkshire.[5] Unfortunately, this building had also been demolished. Further discussion about Peckitt's work indicates that he often mounted stained glass in suspended frames, therefore the "strong glass" may have only served to strengthen an autonomous panel or "sun-catcher" of sorts, rather than the role of "PG" in terms of this study.

3. As initially reported in the British Society of Master Glass Painters (#8, 408) communications, the Collins-Martin window at Redbourne, Lincs. had outer glazing in iron frames, set before 1845.

Several other 19th century PG installations were documented elsewhere in Europe and reported by Stefan Oidtmann in his published dissertation entitled Die Schutzverglasung - eine wirksame Schutzmaßnahme gegan die Korrosion an wertvollen Glasmalerieien (December, 1994).

4. The great northeast windows at the Orvieto Cathedral, Orvieto, Italy, were covered with PG sometime between 1826-1886. Unfortunately, this 19th century installation is not well documented but deserves to be recognized.

5. In 1897, the windows of the small Romanesque church of Lindena (Mark Brandenburg, Germany) were protectively glazed by Dr. H. Oidtmann, Linnich, Germany; the installation was probably installed to protect the window from environmental deterioration.

6. Gabriel Mayer of Franz Mayer'sche Hofkunstanstalt, Munich recalled his father and grandfather mentioning, though he has no documentary evidence since the company records were destroyed in 1944, that 19th century Mayer & Co. and F.X. Zettler (Munich) installations sometimes included large sheets of clear glass for protective purposes.

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[4]CVMA Newsletter 13, February 21, 1975.

[5]CVMA Newsletter 13 & 14. February 21, and April 21, 1975.

Given the abundance of stained glass in Europe, and the few PG installations recorded, it is readily apparent that the usage of PG during the 19th century in Europe can only be described as rare at best. Its limited use continued until W.W.II. Then the perceived value of PG changed drastically. For most of their history, the major cathedrals throughout Europe had established restoration programs, but few had pressing concerns regarding the deterioration of stained glass from atmospheric pollution and moisture. When these great windows were systematically removed for protection from aerial bombing, a unique opportunity to document them arose. Upon reinstallation, the resulting photo survey showed enormous damage to the paint and glass caused by damp storage below ground. As a result of this new awareness, many windows such as those at Cologne, Regensberg, and Munich were automatically covered with protective glazing upon reinstallation after the war.

Further studies of medieval glass corrosion caused by acid rain since W.W.II have strongly influenced the Europeans to cover their windows with PG. In Germany, protective glazing became common with the repair and restoration of churches since the mid 1950s. Since then, protective glazing has become common throughout Central Europe and in Austria as well as the Netherlands. Gabriel Mayer, a principle of the **Franz Mayer'sche Hofkunstanstalt**, Munich concurred with this observation and noted that his company reinstalled many windows with protective isothermal glazing in Germany in the 1950s. Most of these installations were reportedly vented. The Canadian studio that responded to the questionnaire always installs PG while the European studios from Hungary and England indicated that they only promote its use under specific conditions. France has only recently begun to use protective glazing. Considerable scientific study of European PG installations and their effect on stained glass, particularly medieval glass, has been undertaken since W.W.II. This research is covered in *Section V.*

HISTORY OF PROTECTIVE GLAZING IN THE U.S.

Stained glass was installed on a very limited basis in America before the 1830s and was not commonly used until the 1860s. Prior to the 1860s, most of the stained glass in the U.S. was imported from England, Germany, Holland, France and other European countries. Imported plate glass was available in America by the late 1830s but it was expensive. Like Europe, the use of protective glazing in the United States during the 19th century was extremely rare. Additional "strong glass" to fill a window opening with a second layer could not be justified when the stained glass already served to keep the weather out. Glass making technology in the U.S. evolved throughout the mid 19th century and eventually inexpensive domestic plate glass was available for use as protective glazing.

Several attempts to manufacture plate glass in the U.S during the 1850s ended in failure, and the first "truly successful" plate glass enterprise, the **New York Plate Glass Company**, was not established until 1880 in Creighton, Pennsylvania; the company changed its name to the **Pittsburgh Plate Glass Company** in 1883.[6] Although defined as an "infant" industry in 1879, new technology reduced manufacturing costs and the cost of plate glass to the consumer dropped

[6]Glass Incorporated. The Miracle of Glass, 1939. pg. 22.

by 50% between 1879 and 1884.[7] As American ingenuity spread through the glass industry, the domestic output of polished plate rose to 82% by 1890, while rough plate (more commonly used for PG) rose to 97%.[8] Further, domestic plate glass production tripled from 1,055,224 s.f. in 1890 to 3,342,573 s.f. in 1919.[9] This growth is attributable to technological improvements in plate glass manufacturing. A U.S. patent for tempered glass was issued on December 15, 1874; tempered glass is stronger and more difficult to fracture than ordinary glass. In 1897, the **Marsh Plate Glass Company** in Floreffe, Pennsylvania, installed the first continuous lehr for annealing plate glass, *"to anneal plates by means of the old-type oven required about three days; the continuous lehr reduced this time to three hours."*[10] With these developments and others, American machinery was being sought abroad. Electric-powered grinders and polishers also played a significant role by 1900.

Until the first World War, however, plate glass was produced almost entirely by the "casting" method, both in the U.S. and Europe. Glass was melted in regenerative pot furnaces. The pots were removed from the furnaces by a crane, skimmed, and partly inverted over a flat, cast iron casting table which was covered with fine sand to prevent the glass from sticking or chilling to quickly. The molten glass was poured in a continuous stream just ahead of an enormous water cooled cast-iron roller. The roller was lifted and the glass removed to a series of lehrs. It was now rough-rolled glass. Polishing the rough-rolled glass was costly. Various pieces of rough glass were fitted onto a plaster bed, on a circular table up to 30 feet in diameter **[FIG 9.]**. The table was transferred to a grinding frame where large iron disks, supporting smaller iron disks, were spun on the sheets with increasing pressure. First coarse sand and water, then finer sand, and finally emery and water were fed to the grinding surfaces, gradually wearing away irregularities. The process took about one hour. The table was used again for polishing, using felt wheels and a finer abrasive, rouge (iron oxide) and water. Upon completion of the grinding and polishing, the rough plate was half its original thickness.

Prior to 1889, it took nearly ten days to produce a piece of polished plate glass from the raw materials. Max Bicheroux of Germany developed a new type of rolling machine shortly after the first World War. His machine produced sheets of predetermined length in a semicontinuous process. In 1922, U.S. automaker Henry Ford introduced continuous rolling in the manufacture of autoglass and revolutionized the American glass industry-- soon to be the largest producer of plate glass in the world. Making the blank, grinding and polishing were now automatic and continuous, just as an assembly line. This process was adapted by **Libby Owens Ford Glass Co.** in 1925. By the pot casting and continuous rolling method of 1922, it took just 54 hours,

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[7]Pittsburgh Plate Glass Company: Glass, pg. 31.

[8]Scoville, Warren C. Revolution in Glassmaking. pg. 52.

[9]Ibid. pg. 70.

[10]Scoville, Warren C. Revolution in Glassmaking. pg. 335.

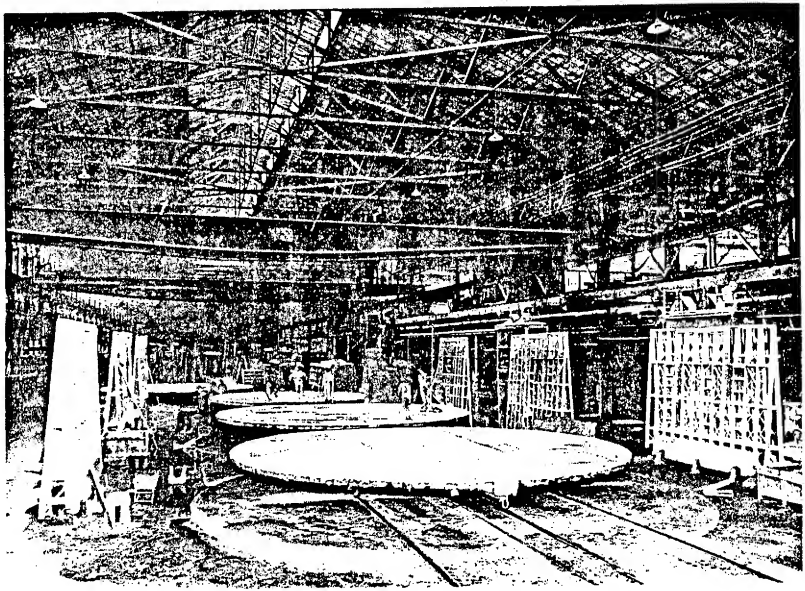

Fig 9. Workmen tramp sheets of rough glass into wet plaster for grinding.

while the semicontinuous method of 1925 further cut production time to only 22 hours! With the introduction of ever larger sheets of glass through ever increasing technical efficiency, resulting in ever lower costs, double glazing became ever more common.

The American development of plated opalescent windows by John LaFarge, Louis Comfort Tiffany and their followers may have lead to the earliest use of protective glazing in the United States. Plated opalescent windows, consisting of several layers of glass, inherently called for the use of large outer glass plates to keep dirt and moisture out of the window interspaces. The exterior plate(s), integral with the window, effectively served as PG. Many plated windows were installed throughout the country by the early 1890s, but most are not representative of the typical PG installation **[Fig 10.]**. Within a decade, plated windows were sometimes covered with a full back-plate of rough (unpolished) or ribbed plate glass. A recent restoration of 1902 plated windows found at Old St. Paul's in Baltimore, and made by Maitland Armstrong (a Tiffany colleague), appear to have had original "textured" protective glazing. This exterior glazing was set in an iron frame and bolted to the angle-iron sash holding the stained glass.[11]

Fig 10. A large piece of glass is removed from a plated Tiffany window.

[11]Diane Roberts, "A Portrait of Maitland Armstrong," PSG's Glass Artist, April/May, 1995 p.16.

There are reports of domestic ribbed plate glass installed over German imports from the late 19th century in the Northeast. However, Theodore C. Von Gerichten, whose grandfather founded **Von Gerichten Art Glass Company** (Columbus, OH) in 1893, does not recall any practice of installing PG over their domestic windows or those they imported from Munich, Germany. A search through hundreds of 19th century and early 20th century photos of Chicago churches uncovered no examples of PG over stained glass.

Only two examples of protective glazing in the United States prior to 1900 have been substantiated as part of this study. Both examples represent the usual concept of PG as a separate layer over traditional (single layer) stained glass. St. Thomas Episcopal Church in Taunton, Massachusetts was severely damaged by fire in January 1898. An article in the parish magazine in September 1898 listed repairs and improvements as a result of the fire and noted *"...the rose window guarded against leaks by storm sash."* The Second Church of Christ in New York City has original PG from 1899.

A number of documented PG installations have been identified from the first quarter of the 20th century. The art glass at Wellington Avenue Congregational Church, constructed in a bustling Chicago neighborhood in 1910, was installed in hollow-core steel window frames behind wire safety glass. Crammed into a small site on a residential block, the use of PG may have been motivated by building codes designed to limit the spread of fire rather than any concern for "protecting" the simple art glass. Plated Munich style windows at St. Mary's Church in Beaverville, Illinois, were covered with plate glass provided by the Pittsburgh Plate Glass Company in 1911. Today, several types of plate glass, mostly ribbed, are found on the church.

The **C.J. Connick Collection** at the **Boston Public Library** provides valuable insight on how one of the most prolific American stained glass studios, **Connick Associates**, handled the use of PG in the early 20th century. Although the studio was formed in 1912, protective glazing was not mentioned in company contracts during the first few years in business. However, the Collection contains dozens of references to PG installations starting around 1920 when Hyde Park Baptist (Union) Church in Chicago paid an extra $100 for protection glass in an outside frame. A mausoleum in Rosehill Cemetery, Chicago, was to have *"protection glass furnished by the donor....installed by Temple Art Glass Company,"* an indication that PG was sometimes subcontracted to local glaziers. March 1930 correspondence from the Levere Temple in Evanston, IL to Connick reads *"we have set aside, with protection on the outside, the sum of $5,000, complete, set up."* By the late 1920s, job records in the Connick Collection often indicate whether "protection glass" was ordered or not.

Other early American PG installations include a stained glass window by Willet Studios in Calvary Church, Chestnut Hill, Pennsylvania that was covered with plate glass for $250.^{00} in 1915. The Chapel of St. James of Quigley Seminary in Chicago has ribbed plate glass PG from 1917, while Buena Memorial Presbyterian Church in Chicago has leaded diamond-pane PG from 1922 **[Fig 11.]**. Both of these installations, as apparent with many others around the country, became a protective layer by default. Once available, stained glass was simply inserted behind external glass rather than replacing it. An August 1925 parish monthly from St. Mary of the

Fig 11. 1922 diamond-pane windows became PG for stained glass installed later.

Immaculate Conception (Michigan City, IN) states that the imported F.X. Zettler windows installed from 1925-1927 *"will all be protected against the weather by storm glass."* PG was a frequent option by 1925, the year Mr. Henry Hunt spoke on "Setting Storm and Leaded Glass" at the **National Ornamental Glass Manufacturers Association** conference held in Pittsburgh.

PROTECTIVE GLAZING AND THE BUILDING INDUSTRY

As protective glazing became common to the stained glass industry, it began to attract attention from the architectural community and manufacturers. Good Practice in Construction: Part II, published in 1925 by **The Pencil Points Library**, illustrates a leaded glass window in a stone wall with double glazing and notes *"Extra glass affords protection to the expensive Leaded Art Glass from the weather and possible exterior damage, Also gives added heat insulation"* **[Fig 12.]**. No venting of the air space is indicated. The same illustration also describes a *"double double type"* ventilator. **J. Sussman, Inc.**, Jamaica, New York has been making steel windows for churches since 1906 and Jack Sussman believes his father, the company founder, made double-glazed ventilators from the start. A 1926-27 Sweet's Architectural Catalog listing for **The Philadelphia Supplies Co., Inc.** has sectional views of a double glazed window with a 3/4" air space between the storm and leaded glass, and *"double, double"* ventilators **[Fig 13.]**. No venting of the air space is indicated. The company manufactured all-metal window frames and pivot window ventilators and promoted *"fully weatherproof, all-metal ventilators for masonry construction made for double glazing."* Blueprints for Blessed Sacrament Church in Chicago (1937) denote the installation of double glazed windows with a 1" unvented airspace made by **Rossbach Manufacturing Co.**, Chicago **[Fig 14.]**.

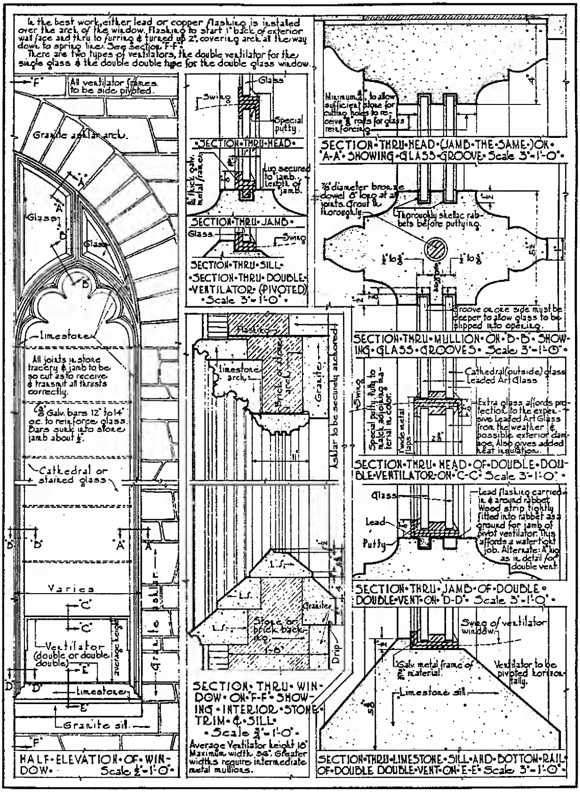

Fig 12. An illustration by The Pencil Points Library (1925) clearly shows double glazing.

ESTABLISHED 1884

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Frames are made of steel or wrought iron as desired. They are built in as the building is in course of construction and make a rigid and everlasting weather-proof job. They are made in all styles—square, round or gothic top, and in any size or weight material desired. Used for leaded, plate, wire, ribbed or prism glass. Finish is either painted or galvanized.

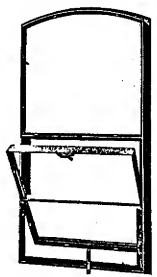
Frames are made for storm glass outside and leaded glass inside or for single glazing.

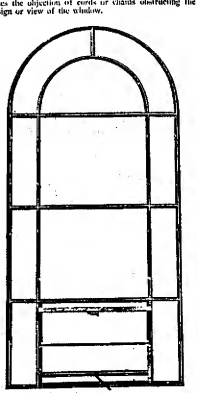
Ventilators can be put in the top, center or bottom of frames, and the inside swinging frames can be removed for glazing.

"Deissler" Improved Pivoted Ventilators

These ventilators have been specified for over 40 years as the standard church window ventilator. They are made of steel or wrought iron angles for single or double glazing and can be used for leaded, plate, wire, ribbed or prism glass. The inside frame of ventilators can be taken out and bars put in to suit the design. Finish is either painted or galvanized.

Where ventilators are in reach they are provided with spring lock at the top and lug at the bottom with strap for adjusting extent of opening. Ventilators out of reach should be specified with bottom heavy, self-closing; these are for the intermediate and bottom sections of windows. They are equipped with lock, pulley, bracket and chain fastener attached to the ventilator and are operated from the side with a chain. This eliminates the objection of cords or chains obstructing the design or view of the window.





Two Stock Designs of Frames That Are Reasonable in Price

We also make special designed metal frames—any style, size or weight material desired

SWEET'S CATALOGUE

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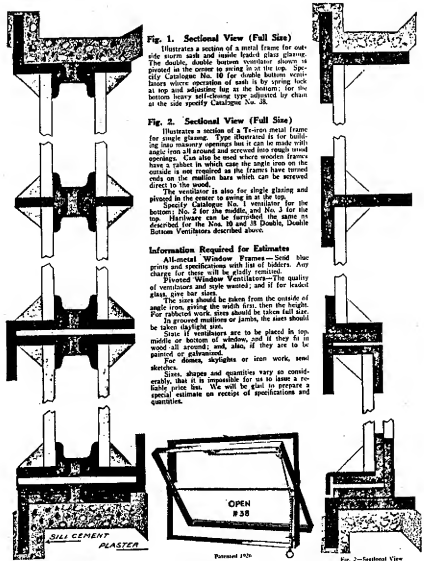

Fig. 1. Sectional View (Full Size)

Illustrates a section of a metal frame for outside storm sash and inside leaded glass glazing. The double, double bottom ventilator shown is pivoted in the corner to swing in at the top. Specify Catalogue No. 10 for double bottom ventilators where operation of sash is by swing lock at top and adjusting lug at the bottom; for the bottom heavy self-closing type adjusted by chain as the side specify Catalogue No. 38.

Fig. 2. Sectional View (Full Size)

Illustrates a section of a T-bar metal frame for single glazing. The one illustrated is for building into masonry openings, but it can be made with angle iron grounds and screwed into rough wood openings. It can also be used where wooden frames are set in cement in which case the angle iron on the outside is omitted as the frames have turned ends on the mullion bars which can be screwed direct to the wood.

The ventilator is also for single glazing and pivoted in the corner to swing in at the top.

Specify Catalogue No. 1 ventilator for the bottom; No. 2 for the middle, and No. 3 for the top. Hardware can be furnished, the same as described for the Nos. 10 and 38 Double, Double Bottom Ventilators described above.

Information Required for Estimates

All-metal Window Frames—Send blue prints and specifications with list of bidders. Any charge for these will be gladly remitted.

Pivoted Window Ventilators—The quality of ventilators and style wanted; and if for leaded glass, give bar sizes.

The sizes should be taken from the outside of angle iron, giving the width first, then the height. For rabbeted work sizes should be taken full size.

In grooved mullions or jambs, the sizes should be taken daylight size.

State if ventilators are to be placed in top, middle or bottom of window, and if they fit in wood all around, and, also, if they are to be painted or galvanized.

For domes, skylights or iron work, send sketches.

Sizes, shapes and quantities vary so considerably, that it is impossible for us to name reasonable price lists. We will be glad to prepare a special estimate on receipt of specifications and quantities.

Fig. 1—Sectional View (Full size)

Patented 1920

No. 38 Bottom Heavy Self-closing Ventilator

Fig. 2—Sectional View (Full size)

Details of P. Deissler & Bro. Pivoted Ventilators and Metal Frames

SWEET'S CATALOGUE

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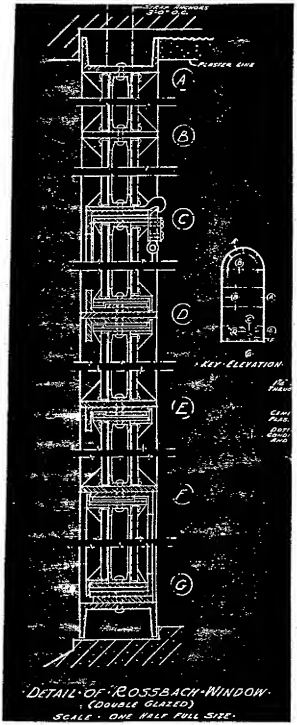
Fig 13. The Philadelphia Supplies Co., Inc. advertised double glazed windows in Sweet's catalog (1926-27).



Blessed Sacrament Church, Chicago

May, 1937

From Blueprints by McCarthy, Smith & Eppig

Fig 14. Double glazing was occasionally specified for churches by the late 1930s.

Stained glass has always served a specialized market, complicating the research for double glazing. **The Philadelphia Supplies Co.** was the only one out of 15 steel window companies listed in the 1926-27 Sweet's to promote double-glazing. Most of the manufacturers targeted the industrial market which had little need for PG. The Great Depression brought church construction to its knees which further limited the demand for decorative luxuries, like stained glass. Although PG was becoming more readily accepted in the U.S., it still remained the exception rather than the rule before W.W.II.

In residential construction, the notion of glass storm windows as "double glazing," did not become popular until after the Civil War. Storm sashes are regularly available in sash & blind company catalogs by 1900. The catalogs tout the benefits of storm windows in terms of energy savings, greater comfort, and the ability to prevent illness. **Noelke-Lyon Manufacturing Co.** (Burlington, IA) asked *"Why should any one be without these items (storms) that easily save their cost in a few seasons"*[12] **[Fig 15.]**. Early residential storms were often installed on hooks or hinges for easy seasonal installation and removal; they usually had elliptical holes on the bottom rail that served as hand-holes and vents during unseasonably warm weather. By the 1920s, extruded rubber weatherstripping led to double insulated steel casement windows featured in the 1924 Audel's Carpenters and Builders Guides. But these windows had limited success as single-pane steel windows remained prevalent until the 1950s.

The architectural firm of Keck & Keck (Chicago) designed the first thermalpane window as a sealed unit in 1935 to alleviate condensation and dirt. By 1941, double-hung and casement thermalpane windows were commercially available in wood or steel. *"By building a wall of captive air, the inner pane is kept comparatively warm even though the outer pane may be very cold. This greatly decreases the heat transmission through the window and simultaneously, eliminates foggy windows and dripping sills."* [13] Energy tests at that time indicated a savings of 23% to 36% for double-glazing. Further studies in the *Architectural Forum* and *American Builder* revealed that in many cases *"double glass insulation pays for itself in 2 years or less, in fuel savings alone."*[14] These studies were likely developed for houses (24-hour occupancy) and it is important to note the reference to double glazing in such emphatic terms. Without any published concerns for how intermittently-used buildings (e.g. churches, synagogues, auditoriums) should be heated, someone reading this in the 1940s might conclude that if double glazing is so effective in terms of energy, it should be used everywhere {see ***Section IV***}. Regardless, the value of double-glazing was further advanced during the 1940s in residential and commercial building markets, which traditionally lead the building industry as a whole.

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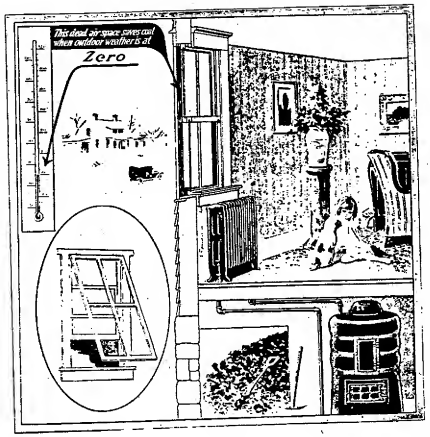
[12]The Noelke-Lyon Manufacturing Co. Catalog, May 1919. pg 60.

[13]C.J. Phillips, Glass: The Miracle Maker, pg. 252.

[14]Ibid, pg. 253.

Storm Sash



People who have these on their homes know the value in saving of fuel, also the additional comfort afforded. Words fail to express adequately the real satisfaction and no one can say how many cases of sickness may be prevented, not to mention the money saved in doctors and medicine. Why should any one be without these items that easily save their cost in a few seasons.

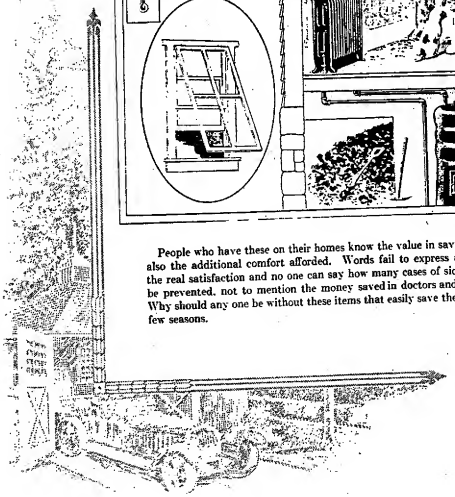


Fig 15. A 1919 storm sash advertisement for residential windows.

Methods of producing stronger glass evolved in the years leading up to, during, and immediately after W.W.II. Even leaded glass was not spared as **super** stained glass, called "Dalle De Verre," was developed in France in 1937. Eventually dubbed "faceted" or "slab" glass in America, such windows can be more than 1" thick and were originally set in a hard cement matrix (now epoxy). Generally less expensive and much stronger than leaded glass, slab glass has grown in popularity since its introduction in the U.S. in the 1940s. Ironically, despite its wall-like strength, PG has been installed in recent years over several slab glass installations in the U.S. **[Fig 16.]**!

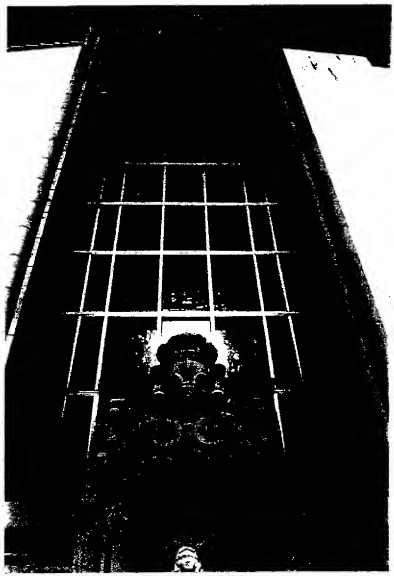


Fig 16. PG was installed over slab glass in 1993 on this church in Phoenix, AZ.

A tempered polished glass advertisement for **Libby Owens Ford (LOF)** appears in the 1950 Sweet's catalog. Sold under the trade name of *Tuf-flex®*, it was made by a process of reheating and sudden cooling, yielding an outer glass surface in a state of high compression which is highly resistant to breakage. Glass treated in this way is three to five times stronger than regular plate glass in sustaining windloads, three times more resistant to thermal shock, and five to seven times more resistant to impact. Tempered glass, like *Tuf-flex®*, shatters if cut and must be made to size specifications before it is tempered-- a purchasing and scheduling hurdle for glazing contractors looking for greater strength and job site flexibility.

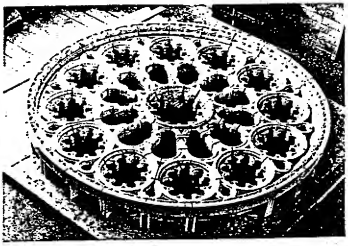
The 1950s saw the introduction of glass alternatives for protective glazing. Alternatives included translucent fiberglass sheets, lead by *Kalwall* in 1955, and a barrage of sheet plastics to follow, which greatly simplified PG installations.

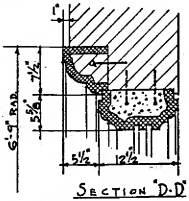
More and more window manufacturers recognized the rapidly changing market after W.W.II and began designing frames to accommodate double glazing. A terra cotta rose window detail by the **Architectural Terra Cotta Institute** from around 1950 shows two pre-formed glazing grooves, one for stained glass and the other for storm glazing **[Fig 17.]**. A **National Metallic Sash Company** (Chicago) brochure illustrates a window sash for double glazing manufactured in brass, bronze, aluminum, steel and stainless steel. According to a company brochure, the **Twin Beam Corp.** (Easton, MA) was incorporated in 1925, but its "twin beam" section was not designed until 1950 and then specifically for churches. *"Sections can be formed in gothic, round-head, square or any other shapes. On church windows, it is possible to reuse the present stained glass, often with minor changes."* The Series 100 was double glazed, 2½" deep **[Fig 18.]**. The outer glass is plain, the inner glass leaded. *"The system is considered highly protective, highly efficient in reducing heating and air-conditioning loads, in reducing transmission of street noise."*

A company brochure for **J. Sussman's** steel windows from the early 1950s shows double glazing in a stone and wood setting. A later catalogue illustrates the 300 Series, an aluminum double glazed church window that Sussman has produced since 1959. The 300 Series *"is specially designed to receive protective glass on the exterior and stained glass on the interior.. This 'Double Glazing' protects the stained glass from vandalism while also insulating from the heat and cold and reduces outside noise infiltration. The insurance and fuel costs can be substantially lower....either glass can be installed without disturbing the other. The exterior glass can be installed at time of erection to close up the building and the stained glass installed at a later date at the churches own convenience."* None of these manufacturers vented the air space.

The commercial availability of sheet acrylics drastically changed the glazing industry and created new opportunities for less-skilled, even unscrupulous, contractors to enter the PG business, increasing competition and sales. Dominating the PG market during the 1960s and early 1970s, the research of acrylic actually dates back to Otto Rohm who initially investigated the polymerization of acrylic for his doctorate in 1901! However, he did not pick up this research again until 1920, seeking to expand his business in the race against similar work in progress at

ROSE WINDOW-a1





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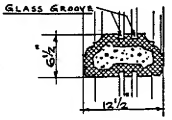

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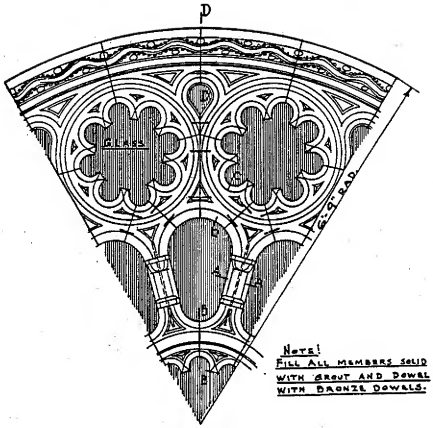
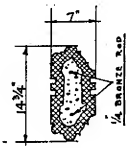
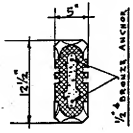




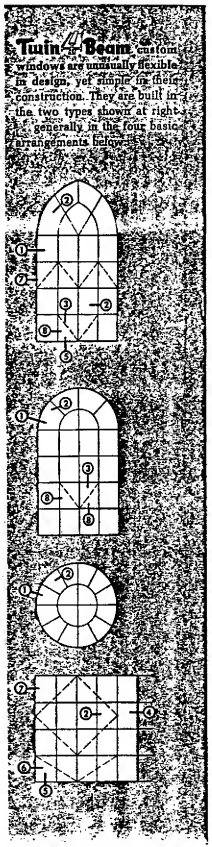
PLAN "B-B"



PLAN "A-A"

ROSE WINDOW-a1 AIA No. 9

Fig 17. Terra cotta units designed for double glazing (ca. 1947-1959).



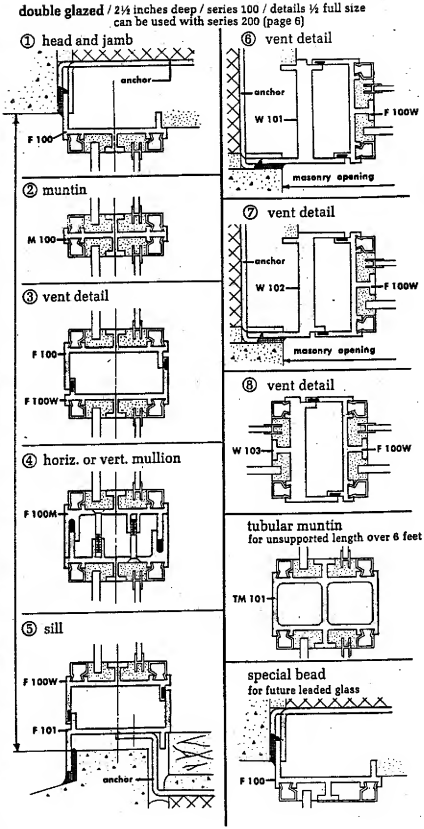


Fig 18. A Twin Beam catalog illustrating double glazing ca. 1950.

Imperial Chemical Industries (ICI) in Britain and at **Du Pont Laboratories (Du Pont)** in the U.S. Eight years later, Rohm and his associate Walter Bauer developed a polymethyl acrylate interlayer for safety glass that was marketed by a U.S. firm as *Plexigum®* in 1931. It was better than celluloid, which yellowed, or cellulose acetate, which became brittle at low temperatures, but it could not compete with polyvinyl butyl, introduced in 1936.[15]

Bauer and Rohm continued experimenting and came up with polymethyl methacrylate, a transparent, glass-like substance that could be sawn, machined and cast in sheets. They also discovered that polymerization occurred through exposure to light. So instead of cementing two sheets of glass together as with *Plexigum®*, this polymer separated cleanly from the glass in a strong sheet. The new material became known as *Plexiglas®* and was commercially available in both Germany and the U.S. in 1936![16]

Du Pont and **ICI** meanwhile continued their own research as well and focused on casting and molding acrylic into rods, tubes and blocks. With the commercial introduction of acrylics looming, and a joint desire to forestall patent litigation, all three companies agreed to an intricate set of cross-licensing agreements in 1936. First, Rohm announced *Plexiglas®*, followed by **ICI** in Great Britain with *Perspex®* and then, **Du Pont** with *Pontalite®*, *"a new, water-clear plastic, strong as glass, flexible and non-shattering."*[17]

Bauer and Rohm's American sister firm, **Rohm and Haas**, obtained a license for casting acrylic sheet from the German firm in late 1935 and in January of 1936 sent Donald S. Frederick to Darmstadt for two months to familiarize himself with acrylic sheet manufacture and fabrication. Frederick then demonstrated *Plexiglas®* to the U.S. Army Air Corps and won a decree stating that polymethyl methacrylate was the only plastic sheet material approved for use in military planes. **Du Pont** did not know exactly how Rohm was casting large acrylic sheets until 1939, but a new license granted **Du Pont** half the annual sheet capacity of **Rohm and Haas**. The name *Plexiglas®* implied a flexible improvement over glass, while **Du Pont's** *Pontalite®* did not. Shortly after its introduction, **Du Pont** dropped the name *Pontalite®* in favor of a new name, *Lucite®*; and soon thereafter, **Du Pont** controlled the U.S. acrylic market.[18]

Laminated glass incorporates both glass and plastic technology. Developed by Bernard Carsten in 1912, it was manufactured by the **Progressive Windshield Company** of Chicago which later became the **Chicago Bullet Proof Equipment Company (CBP)**. The Prohibition era accelerated the need for laminated glass, first for get-away-cars, then for the police, and finally

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[15]Jeffrey L. Meikle, American Plastic: Molding a Culture of New Materials, Rutgers U.P., 1995.

[16]Ibid.

[17]Ibid.

[18]Ibid.

for banks and currency exchanges. **CBP's** specialized line of glazing protects people from people. They also protect stained glass from people-- and natural disasters. Variations of this high impact glazing have found their market in hurricane prone areas, such as Florida.

Laminated glass is comprised of a tough, flexible interlayer of plastic sandwiched between two or more lites of glass. According to the **Glass Association of North America**, laminated glass is made by one of three methods today: 1.) plasticized polyvinyl butyral (PVB) sheet, which includes **Monsanto's** *Safelex*®, **Du Pont's** *Butacite*®, and **Sekisui's** *S-Lec*®; 2.) aliphatic urethane (AU) sheet which includes **JPS Elastomerics** *Stevens*®, and **Deerfield Urethane's** *Dureflex*®; 3.) ultraviolet cured acrylic resin (UV-CAR) which includes **UCB Radcure's** *Uvekol*®.[19] PVB and AU are placed between two or more lites of glass and bonded by heat and pressure (PVB can be either clear or tinted). UV-CAR is a liquid laminating system which crosslinks and bonds to both plastic and glass when exposed to ultraviolet light.

In the late 1980s, **Du Pont** began to mass market a *Butacite*® family of advanced composite glazing products with names such as **Du Pont** *Sentry Glas*®, **Du Pont** *Spallshield*® and **Du Pont** *Butacite*® interlayer. According to company trade literature, these glazing types offer the same natural light and viewing characteristics of conventional window glass, while able to sustain the impact of a nine-pound 2"x 4" traveling at 34 mph, or a 26 pound cinder block at 40 mph. Each of these glazing products feature a *Butacite*® PVB interlayer.

Softer, less brittle, and stronger than acrylics, polycarbonates were first developed as a resin in the 1960s and manufactured in sheets in 1970 by **General Electric Plastics**. **GE** dubbed their product *Lexan*® and its popularity and trade name has become so widespread in the PG industry that many consumers and installers generically refer to any plastic sheet material as "lexan" regardless of the actual product. Although it weighs about the same as acrylic products, the impact resistance of *Lexan*® is said to be 30 times greater than acrylic and 250 times greater than standard glass. Upon installation, the clarity of *Lexan*® is almost that of glass but it will yellow and haze over a few years. **GE** continues to develop new variations such as *Lexan*® *XL*® which is coated with an acrylic non-yellowing ultra-violet protective surface. It has been subject to a three year exposure test and was observed that it tends to bleach, resulting in a clearer product with slightly higher light transmission and less yellowing. *Lexan MR5*® is coated with a silicon abrasion resistant coating called *Margard*® to reduce scratching. Polycarbonates have been the most prevalent material used for PG since the mid 1970s, but chronic aesthetic and technical problems are changing the perception of this incredibly strong material.[20]

Today, protective glazing technology has evolved to the point of triple-glazing! The concept of triple-glazing for stained glass was developed in the wake of triple-glazing for residential and commercial windows by the mid 1980s. Triple-glazed windows were developed in response to

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[19]**Glass Association of North America**, Laminated Glass Design Guide, 1994. pg. II-1.

[20]GE Plastics trade literature on Lexan.

increasing demands for energy performance; important concerns for buildings and spaces occupied for long periods of time -- which is not typical of most worship spaces surrounded by stained glass.

Nevertheless, some consider triple-glazing the "cutting edge" of protective glazing. The Mormon Church, considered to be among the best builders of energy-efficient churches, is reportedly specifying triple-glazed window units on all new Mormon churches. **J. Sussman** currently offers two triple-glazed window types, the 5200 Series and the 5600 Series **[see Section III]**. The 5600 Series is incorporated into a 3½" thermally broken frame and *"can accommodate 1" protective insulated glass with another 5/8" inch minimum air space between the art glass to maximize the protection and insulation of the art glass...The separation of art glass and protective glass is achieved by a channel that is an integral part of the extrusion (not an add-on piece). This channel acts as a condensation gutter and helps prevent air and water infiltration."*

Custom made triple-glazed units are also being fabricated today where the stained glass is sandwiched between (not behind) outer glass layers. These triple-glazed units are discussed in further detail in **[see Sections III & V]**.